



## Spanning the Horizon of Accuracy of Different Intraoral Radiographic Modalities: A Systematic Review

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### ABSTRACT

**Aim:** This study was conducted with an aim to systematically review the literature for assessing the accuracy of intraoral radiographs in detection of dental caries.

**Introduction:** Despite the advancements in oral disease science, dental caries continues to be a worldwide health concern, affecting humans of all ages. Correct diagnosis of caries is critical both in clinical practice as well as in epidemiology and radiography are worthwhile adjunct for a thorough examination.

**Results:** A literature review was performed in PubMed Central and Cochrane library, Embase, and Google Scholar, and these databases were searched up to 2016. The primary outcome measure was to assess the accuracy of intraoral radiographs in the detection of dental caries based on sensitivity and specificity. The sensitivity for conventional radiographs for the detection of lesions in enamel (16–68%) and dentin (16–96%) was found to be superior as compared with other modalities of digital radiography, whereas the specificity of digital radiography was found to be superior in detection of lesion in enamel (77–96%) and dentin (84–100%) when compared with conventional radiography. Sensitivity of conventional radiographs was noted to be superior as compared with digital radiography, whereas in terms of specificity, digital was found to be superior to conventional radiographs.

**Conclusion:** Although there was no significant difference between digital and conventional radiography in the diagnosis of caries, conventional radiographs were able to detect carious lesion, in general, but for lesion to be detected precisely, digital was found to be superior.

**Clinical significance:** As digital radiography produces lower ionizing radiation, dental professionals should employ this method in their routine dental practice for diagnosing and treating carious lesions.

**Keywords:** Dental caries, Radiography, Sensitivity, Specificity.

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### INTRODUCTION

Dental caries has been the most prevalent chronic disease affecting human beings since a long time.<sup>1</sup> It is ubiquitous in all populations worldwide, and is the prime factor responsible for dental pain and tooth loss. Individuals are predisposed to this disease throughout their lifetime. Today, the greatest obstacle in caries identification concerns the carious lesion in the initial stages, when it is confined to the enamel layer.<sup>1-3</sup> As it has turned out more problematic to diagnose caries in clinical practice, numerous diagnostic methods are being improved and others are being developed. Examples incorporate laser fluorescence, transillumination, electrical conductance measurement, electrical impedance measurement, digital imaging, and imaging processing for caries detection.<sup>3</sup>

### Description of the Disease Condition

Dental caries is a multifactorial disease with interaction among four factors: Host, diet, time, and microbial flora.<sup>2</sup> Development of caries requires both presence of bacteria and fermentable carbohydrates. *Streptococcus mutans* and *Streptococcus sobrinus*, two species of the mutans streptococci, are the most significant in human caries. These bacteria are opportunistic pathogens, found frequently as members of the resident flora of persons without caries and expressing their pathogenicity only under precise environmental conditions. Studies of the microbial ecology of caries have been directed notably at these species and there was a solid link between *Lactobacillus* species and caries.<sup>4</sup> Composition of tooth, such as deficits

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in fluorine, lead, zinc, and iron content of the enamel are accomplice with progressive caries.

In addition, deep, narrow occlusal fissures and lingual and buccal pits tend to trap food debris and bacteria, which can cause tooth decay. The interdental areas and malalignment of the teeth, such as crowding and unusual spacing can upsurge the vulnerability to caries.<sup>5-8</sup> The role of refined carbohydrates, especially the disaccharide sucrose, in the etiology of dental caries is well established. The quantity of sugar ingested, its oral clearance rates, and frequency of consumption are important factors in the etiology.<sup>9-12</sup>

### Description of the Diagnostic Test

Visual clinical examination is one aspect of detecting caries; however, several areas of the tooth are not visible to the human eye including below fillings, at the contact point of teeth, and below the gingival (gum) level. In addition, the changing nature of dental caries, resulting in slower progression of demineralization and later cavitation, has resulted in deep invasion of dentin, which is concealed under enamel that superficially appears to be intact.<sup>13</sup> Therefore, to aid visual examination, radiography may be used as an adjunct to the clinical examination for the recognition of caries.<sup>2</sup> Radiographs are an essential part of dental diagnosis and treatment planning.

Periapical radiography is a habitually used intraoral imaging technique in dental radiology. A periapical radiograph offers valuable information about the teeth and adjoining bone. The film shows the entire tooth structure that provides imperative information to aid in the diagnosis of the most common dental infections, specifically tooth decay, tooth abscesses, and periodontal bone loss or gum disease. Additional significant findings may be detected, including restorations, calculus or tartar, impacted teeth or broken tooth fragments, and disparities in tooth and bone anatomy.

Bitewing examinations were introduced by Dr Raper in 1925. Bitewing images focus on the clinical crowns of both maxillary and mandibular teeth. Bitewings do not show the apices of the tooth and cannot be used to diagnose in this area. The enormous role of bitewing radiographic images is in the detection of interproximal caries in the primitive stages of development, before it is clinically apparent. Bitewing images also affirm the size of the pulp chamber and the relative extent to which proximal caries have penetrated.<sup>14,15</sup>

There are two ways a digital dental radiograph can be produced: (a) Using a charge-coupled device (CCD) connected to a computer \ Radiovisiography (RVG) and (b) by the use of photostimulable phosphor (PSP) imaging plates. The CCD uses a thin wafer of silicon as the basis for image recording. The silicon crystals are formed in a picture element (pixel) matrix. When it is exposed to the

radiation, the covalent bonds between silicon atoms are broken, producing electron-hole pairs.

The primary advantage of digital radiography over conventional techniques is in image storage and manipulation. A digital image may be manipulated to optimize contrast in a particular area of interest, and then stored on a picture archiving system (PACS) allowing the image to be retrieved at will and shared with other professionals. Digitization of conventional images allows storage on a PACS system, but requires a large number of processes to achieve the final image, and is dependent on great operator care to produce a high-quality final image.<sup>16</sup>

### Why is it Important to do This Review?

Radiography along with clinical findings is considered as a usual diagnostic approach for caries detection. Unfortunately, there is not a quite sensitive and precise method available for the early detection of caries at the present time. Therefore, sensitive diagnostic techniques are required for a wide range of applications for individual patient care as well as for research purposes to provide acceptable compromises between sensitivity and specificity. Hence, it is now universally recognized that the development of new technologies for the detection and quantification of dental caries at an early stage of its formation could provide health and economic benefits ranging from timely preventive interventions.<sup>17</sup> Although there is an ongoing search by the researchers for the tools with acceptable sensitivity and specificity for this purpose, different revelations have expressed that none of these new methods and common available devices are capable to detect caries. It has been shown that enamel lesions are less underestimated than dentin lesions. However, there seem to be no studies published to date investigating the accuracy of caries lesion detection using intraoral radiographs as well as digital radiographic technique.

### Objective

#### Research Question

To assess the accuracy of intraoral radiographs based on sensitivity and specificity among subjects...! OR

To compare the accuracy of intraoral radiographs with different radiographic techniques among the subjects.

### MATERIALS AND METHODS

#### Eligibility Criteria

The articles which are published in English dated from the year 1986 to 2016 were included in this review. The search terms for articles were the terms either in the title or abstract. Full-text original articles were taken. Unpublished articles in press and personal communications, etc., were screened and excluded from the study.

**Inclusion Criteria**

- Studies evaluating the use of intraoral radiographs were included in the study
- All the original research articles were included in the study
- *In vivo* studies
- *In vitro* studies
- Inclusion of sensitivity, specificity as outcome variable.

**Exclusion Criteria**

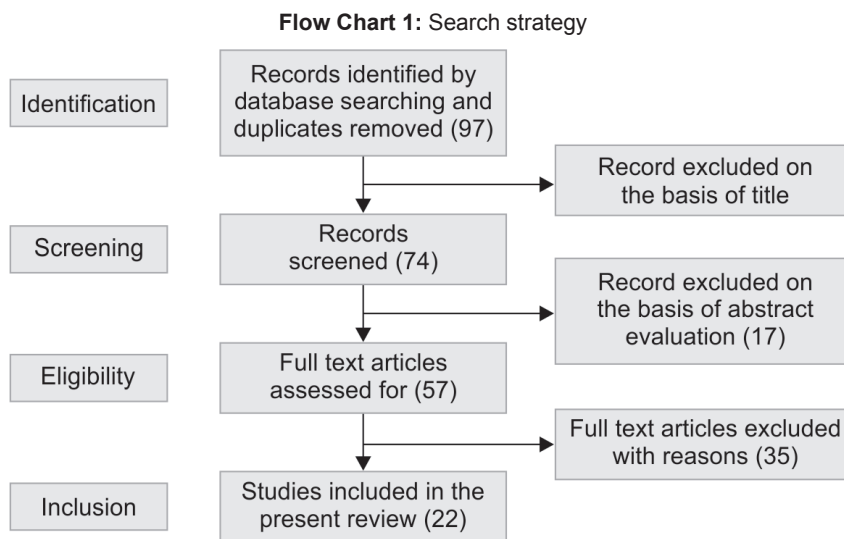
- Narrative review articles
- Summary articles.

**Search Strategy**

Search method for identification of studies: For the identification of the studies included in this review, we devised the search strategy for each database. The search strategy used a combination of controlled vocabulary and free text terms. The main database was PubMed, PubMed Central, Cochrane Review, Embase and Google Scholar (Flow Chart 1)

**RESULTS**

A total of 15 studies were included to check the accuracy of intraoral radiographs for the detection of dental caries. The summary of the results has been provided in (Tables 1 and 2).



**Table 1:** Summary of the results of in-vitro studies

Citation method	Sample size	Modality used	Criteria	Sensitivity	Specificity	Type of lesion	Interpretation
<i>In vitro</i>							
Abesi et al <sup>1</sup>	72	Film radiography CCD PSP	Lesion in enamel only Lesion in enamel and dentin both	0.38 0.15 0.23 0.55 0.45 0.55	0.98 0.96 0.98 1 1 1	Approximal	No significant difference found between digital and conventional radiography in the detection of noncavitated interproximal caries
Haiter-Neto et al <sup>18</sup>	100	Conventional film PSP	Lesion in dentin	0.31 0.31	0.93 0.95	Approximal	There is no statistically significant difference (p > 0.05) for the detection of dentinal lesion
Pontual et al <sup>3</sup>	160	3 Intraoral PSP system Conventional film	Lesion in enamel	0.14 0.14 0.15 0.16	0.93 0.94 0.89 0.92	Approximal	There is no statistically significant difference (p > 0.05) found between PSP system and conventional film in detection of lesion in enamel

(Cont'd...)



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(Cont'd...)

Citation method	Sample size	Modality used	Criteria	Sensitivity	Specificity	Type of lesion	Interpretation
Nytun et al <sup>19</sup>	30	Visual Radiographic Combined visual radiographic	Lesion into dentin	0.72 0.66 0.86	0.41 0.50 0.64	Occlusal	There was a statistically significant difference between combined visual radiographic and isolated visual or radiographic alone ( $p = 0.00$ ) but not between isolated visual or radiographic ( $p > 0.05$ ) for the detection of lesion in dentin
Attrill and Ashley <sup>20</sup>	58	Visual Radiographic (bitewing)	Lesion in enamel Lesion in dentin	E1-0.64 E2-0.54  E1-0.29 E2-0.36	0.85 0.96  1 1	Occlusal	Visual produced high sensitivity and specificity as compared with bitewing. There is no statistically significant difference between visual and radiographic method for the detection of lesion in enamel and dentin
Chong et al <sup>21</sup>	320	Visual tactile Conventional (bitewing) Digital	Lesion in dentin	0.81 0.90	0.44 0.58	Occlusal	There is a significant difference found between visual-tactile compared with conventional, visual tactile with digital, conventional with digital for the detection of lesion in dentin
Kühnisch et al <sup>22</sup>	54	Visual Films (E,F) PSP	Lesion in dentin	Light microscopy Visual-0.68 E-film 0.76 F-film 0.64 PSP-0.60 Micro radiography Visual-0.682 E-film 0.773 F-film-0.682 PSP -0.591	Light microscopy Visual -0.931 E-film 0.786 F-film 0.679 PSP -0.857 Micro radiography Visual -0.875 E-film 0.742 F-film 0.677 PSP -0.806	Occlusal caries	The sensitivity of the E-speed film was 76.0% (microscopy) and 77.3% (microradiography) and amounted to 64.0% and 68.2% for the F-speed film and was lowest for digital radiography with 60.0% and 59.1%, respectively. A reverse tendency could be observed for the SP—the highest specificity values were recorded in connection with digital radiography In accordance with the diagnostic performance, the digital system can be recommended for practical use
Espelid and Tveit <sup>23</sup>	151	Visual Film	Lesion involving DEJ	0.69	0.89	Proximal	Frequency of sensitivity and specificity varied greater for film because of different diagnostic criteria used by observer
Mileman and van der Weele <sup>24</sup>	105	Microradiography Films	Lesion into outer dentin	0.54 0.79	0.97 0.95	Proximal	Sensitivity was quite higher for films, while no diff. in specificity
Russell and Pitts <sup>25</sup>	120	Films (D,E) RVG	Lesion reaching DEJ	D-film 0.29 E-film 0.30 Rvg-0.16	0.92 0.96 0.96	Proximal	There is no significant difference between films and RVG. For approximal caries, the specificity of RVG videoprints was similar to that of bitewing radiography, but the sensitivity was slightly lower for RVG
Ricketts et al <sup>26</sup>	96	Film	Lesion into dentin	0.16	0.99	Proximal	There was no statistically significant diff. found between D and E speed films
Wenzel and Fejerskov <sup>27</sup>	78	Visual Conventional Digital	Lesion into dentin	E-film 0.48 Digitized film 0.71	0.81 0.85	Occlusal	Sensitivity and specificity for digitized film was found to be greater than for E-film

**Table 2:** Summary of the results of in-vivo studies

Citation method	no.	Modality used	Criteria	Sensitivity	Specificity	Type	Interpretation
<i>In vivo</i>							
Fracaro et al <sup>28</sup>	481	Visual Bitewing	Lesion in dentin	0.96	0.58	Occlusal	There is a statistically significant difference between visual and bitewing radiographs ( $p < 0.001$ ) for the detection of lesion in dentin
Goel et al <sup>29</sup>	52	Visual Bitewing	Lesion in enamel Lesion in dentin	0.481 0.493 0.527 0.305	1 0.50 0.893 0.829	Occlusal	Both visual and tactile methods had a tendency to underscore enamel carious lesions as sound in 80% of the cases. Dentin carious lesion could be detected correctly in 52.8% of the cases by visual examination, sensitivity was lowest (48–53%) for visual and tactile methods for detection of occlusal caries lesions at both enamel and dentin cutoff limits. Bitewing radiographic examination provided no added benefit over visual examination for detection of occlusal carious lesions at both enamel and dentin cut-off limits, whereas for detection of dentinal caries, even though the sensitivity was high, accuracy of the other device was similar to other conventional caries diagnostic methods
Coutinho and da Rocha Costa <sup>30</sup>	30	Visual Bitewing	Lesion in dentin	0.14 0.80	0.43 0.75	Approximal	The radiographs were perfectly capable of diagnosing decayed surfaces, but with low specificity for diagnosing sound surfaces, while the clinical examination alone was not able to detect which areas were sound or decayed. Bitewing was useful for detection of decayed surfaces, but with low specificity for diagnosis of sound surfaces. The combination of methods was effective in obtaining an accurate diagnosis of caries in the primary dentition

## DISCUSSION

The diagnostic accuracy and applicability of commonly used methods require a comprehensive research to discern the advantages, limitations, and further improvements to be achieved in the interest of the patients and dentists.

The most frequently used indicators of diagnostic performance have been sensitivity and specificity. The diagnostic methods reviewed in this particular review are visual inspection, conventional (bitewing), and digital (CCD/RVG and PSP). An ideal diagnostic method should provide high sensitivity and specificity. However, a high sensitivity is normally obtained at the expense of reduced specificity. This condition would increase the number of false positive diagnosis, which can be dangerous, as it can lead to over treatment of dental caries. Thus, it seems to be more convenient for a method of caries detection to have a high specificity even at the expense of a small reduction in sensitivity.<sup>31</sup> For the enamel lesion, among the intraoral diagnostic modalities reviewed, least sensitivity was found to be 0.14 for the digital, i.e., PSP, and highest sensitivity was found to be 1 for visual followed by 0.68 for conventional. Sensitivity of visual inspection in detection of enamel lesion ranged from 0.48<sup>32</sup> to 1,<sup>4</sup> the findings are in agreement with the study done by

Attrill and Ashley<sup>20</sup> (0.6–0.7), whereas sensitivity for conventional radiographs was in the range of 0.16<sup>3</sup> to 0.68.<sup>4</sup> The findings are consistent with the studies conducted by Abesi et al<sup>1</sup> (0.38), Goel et al<sup>29</sup> (0.493), and Attrill and Ashley<sup>20</sup> (0.54–0.64). The sensitivity for digital radiographs was found to be in the range of 0.14<sup>3</sup> to 0.64<sup>4</sup>; these are consistent with the findings of study done by Abesi et al<sup>1</sup> (0.1–0.23).

The specificity for enamel lesion was found to be lowest for conventional radiography, i.e., 0.50<sup>32</sup> and it ranged between 0.50<sup>32</sup> and 0.98<sup>1</sup>; the findings are in agreement with study done by Pontual et al<sup>3</sup> (0.92), Attrill and Ashley<sup>20</sup> (0.82–0.85), and Dias da Silva et al<sup>4</sup> (0.68–0.77). For enamel lesion, the highest specificity was found for visual, i.e., 1<sup>32</sup> followed by 0.98<sup>1</sup> for conventional and digital both.

For visual inspection, the specificity in enamel lesion ranged between 0.6<sup>27</sup> and 1<sup>32</sup>; the findings are consistent with the study conducted by Dias da Silva et al<sup>4</sup> (0.77), whereas in digital, it was in between 0.77<sup>4</sup> and 1<sup>1</sup>; similar findings were also noted in the studies conducted by Pontual et al.<sup>3</sup> The study done by Abesi et al<sup>1</sup> in 2009 showed that the highest and lowest sensitivities for enamel caries were related to film and CCD respectively.

In noncavitated lesions, the diagnostic accuracy improved with increase in the depth of the lesions. In

enamel lesions, film (conventional system) had better results, although there was no significant difference ( $p > 0.05$ ) between conventional and digital systems. Another study by Pontual et al<sup>3</sup> also found no statistically significant difference ( $p > 0.05$ ) between PSP (digital) system and conventional system.

Dias da Silva et al<sup>4</sup> in their study found that the visual inspection showed significantly higher sensitivity and accuracy than two radiographic methods—conventional and digital, while no significant differences were found for specificity. Another study by Attrill and Ashley<sup>20</sup> showed no statistically significant difference ( $p > 0.05$ ) between visual and radiographic methods for the detection of lesion in enamel.

For dentinal lesion, among the intraoral diagnostic modalities used in the review, least sensitivity was noted for visual inspection, i.e., 0.12, and highest for conventional radiography, i.e., 0.96. Sensitivity of visual inspection in detection of dentin lesion ranged from 0.12 to 0.89.<sup>4,19,32</sup> The sensitivity for conventional radiography was in the range of 0.16 to 0.96.<sup>1,4,25,33</sup> The sensitivity for digital radiographs was found to be in the range of 0.31 to 0.60 for PSP<sup>1,3,18,22</sup> and 0.16 to 0.69 for CCD/RVG.<sup>4,25,33</sup> The specificity for dentinal lesion was found to be lowest for visual 0.41, although the range of specificity for visual inspection was 0.41 to 0.98.<sup>4,19,32</sup> Highest value of specificity was seen both for conventional as well as digital, i.e., 1. Here, the range of specificity for conventional radiographs was found between 0.50 and 1.<sup>18,20,21,26,34</sup> The specificity for digital ranged between 0.69 and 0.98 for PSP<sup>1,3,18</sup> and 0.77 to 1 for CCD/RVG.<sup>1,4,27</sup> Majority of the studies like Attrill and Ashley<sup>20</sup> and Dias da Silva et al<sup>4</sup> found no statistical significant difference between visual inspection and conventional radiography in the detection of dentinal lesions, but there is a statistically significant difference found in some other studies.<sup>21,28,34</sup>

Another study found a significant difference between combined visual radiographic and isolated visual or isolated radiographs, but not between the isolated visual or radiographic method.<sup>19</sup> This shows that combined use of visual and radiographic examinations is better than either visual or radiographic examination alone. In addition, when visual is compared with digital radiography, there is a significant difference found in the study done by Chong et al.<sup>21</sup> When the diagnostic ability of intraoral digital sensors and the conventional film is compared, there was no statistical significant ( $p > 0.05$ ) difference found in some other studies.<sup>18,25,33,35</sup> However, a significant difference was noted when conventional was compared with digital in the study done by Chong et al.<sup>21</sup>

Russell and Pitts<sup>25</sup> compared conventional bitewing radiographs with RVG video prints from an RVG32000 unit. They found that for occlusal caries,

sensitivity and specificity of RVG video prints were similar to those of bitewing radiography, while for the identification of both dentin and enamel caries, no significant difference was found between conventional and digital radiography in terms of sensitivity and specificity in a couple of other studies.<sup>1,36</sup>

Digital systems have few advantages when compared with conventional film, such as reduced exposure dose, reduced processing artifacts, reduced working time from image exposure to image display, easier image communication, increased diagnostic accuracy, no contamination with processing solutions, and less processing errors. However, some of the disadvantages with the digital systems are rigidity and thickness of the sensor and higher initial costs of the digital systems.<sup>37</sup>

## CONCLUSION

Caries detection can be done through radiography along with clinical inspection, which is a routine diagnostic method. Radiographic diagnosis should only be used after clinical examination considering the dental and general health needs of the patient. Since situations for each patient differ, radiographic examination should be individualized and should consider the initial routine dental examination because the hidden caries can only be detectable radiographically in some patients. Hence, radiography plays a crucial role in the diagnosis of initial and occult dental caries. There is no new method and common devices are present to detect the dental caries in all surfaces of tooth; therefore, researchers are attempting to obtain a new tool that has sufficient sensitivity and specificity for this purpose. Sensitivity of conventional radiographs was noted to be superior as compared with digital radiography, whereas in terms of specificity, digital was found to be superior to conventional radiographs. Hence, conventional radiographs, in general, are able to detect carious lesion, but for lesion to be detected precisely, digital was found to be superior.

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